Fermilab FERMILAB-Conf-03/345-E October 2003

CDF/PUB/JET/PUBLIC/6635
Version 1
August 19, 2003

Hard QCD at the Tevatron

Christina Mesropian

The Rockefeller University

for CDF and DØ Collaborations

Presented at the Conference on the Intersections of Particle and Nuclear Physics (CIPANP 2003), New York City, May 19-24, 2003.

Hard QCD at the Tevatron

Christina Mesropian

The Rockefeller University
for CDF and DØ Collaborations

Abstract. Results from QCD studies at the Tevatron from new Run 2 data are presented. The inclusive jet cross section and dijet mass spectrum are measured at $\sqrt{s} = 1960$ GeV by the CDF and DØ collaborations. CDF also reports results of searches for new particles decaying into dijets, and a study of jet shapes.

INTRODUCTION

The measurement of the inclusive jet cross section represents one of the basic tests of QCD at hadron-hadron colliders. The Tevatron Run I results, in particular the discrepancy between the CDF inclusive jet cross section and NLO QCD calculations, generated substantial interest in the particle physics community and resulted in the revision of existing parton distribution functions (PDFs) [1]. New PDF sets now exploit the flexibility of gluon distributions at high x values, which could account for the excess observed in the data at high E_T. Other important outcomes of jet measurements at the Tevatron, were the measurement of the strong coupling constant from the inclusive jet cross section [2] and inclusion of both CDF and DØ jet results in the global fit by PDF collaborations [3].

The increase in center-of-mass energy and increased luminosity in Run 2 resulted in a dramatically larger kinematic range for measuring jet production. With a data sample similar to that obtained in Run I, both CDF and DØ collaborations are able to measure jet production at much higher E_T than those possible in the previous run. All preliminary results from CDF and DØ are based on data samples collected during the limited time period from February 2002 to January 2003 at Fermilab Tevatron Collider at $\sqrt{s} = 1.96$ TeV.

INCLUSIVE JET CROSS SECTION

The inclusive jet cross section measurement from CDF is based on a data sample of integrated luminosity 85 pb^{-1}. To obtain results in a prompt fashion, the CDF collaboration utilized the same techniques as in Run I inclusive jet analyses [4], when possible. Briefly, jets are reconstructed using the iterative fixed cone algorithm with cone radius R =0.7. The inclusive jet cross section includes all jets in an event in the pseudorapidity range $0.1 < |\eta| < 0.7$. The following data quality cuts are used: events with large missing E_T are excluded to avoid background from cosmic rays, and the event vertex is required to be within 60 cm of the center of the detector, to ensure a good

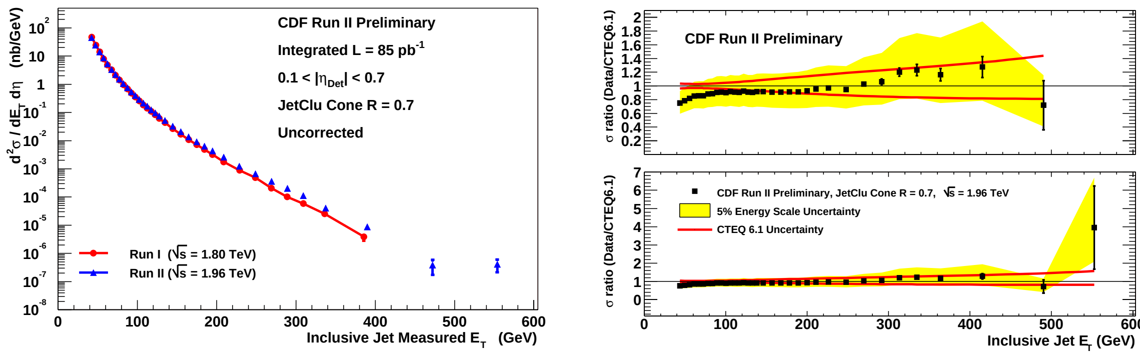

FIGURE 1. (left) The measured inclusive jet E_T distribution for the Run I and Run 2 data sets; (right) the ratio of the measured inclusive jet cross section from Run 2 data to the NLO QCD calculation with CTEQ6.1 PDF.

jet energy measurement. The measured spectrum is corrected for calorimeter response, resolution and underlying event energy using an iterative unsmearing procedure. The absolute energy scale of jets in the central region is calibrated to the known energy of jets in Run I by requiring the p_T balance of central photons to central jets to be the same in Run 2 and Run I. Fig. 1(left) shows CDF Run 2 and Run I jet spectra. The new results are in good agreement with the previous measurement. As one can see, the E_T reach due to the increased $\sqrt{s}$ is rather dramatic, spanning from 40 to 568 GeV. Fig. 1(right) shows the corrected Run 2 cross section compared to a QCD prediction with CTEQ6.1 PDF as an input to the calculations. The shaded area represents 5% energy scale uncertainty, which

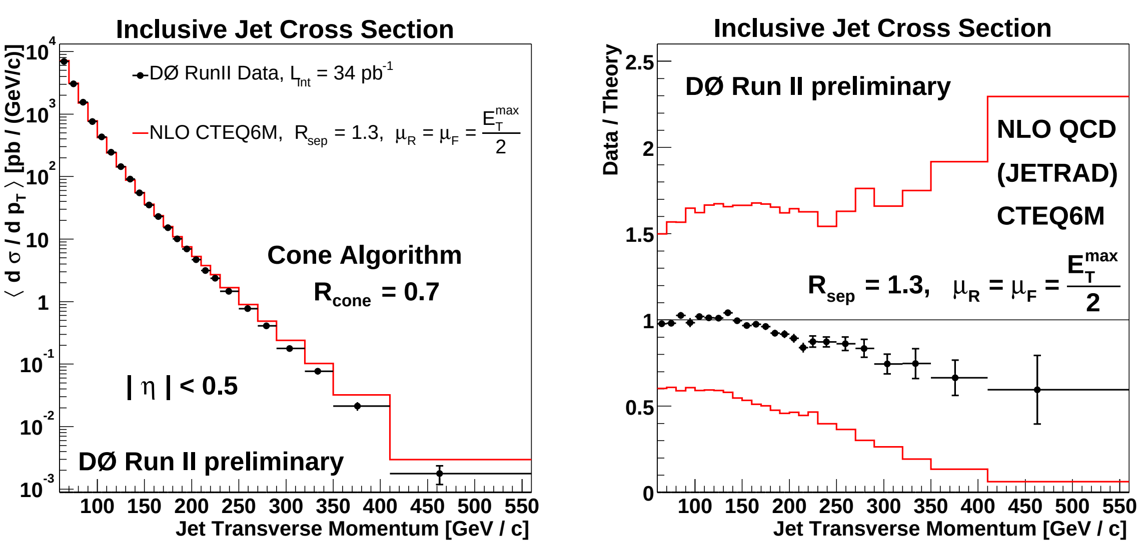

FIGURE 2. (left) DØ inclusive jet cross section as a function of p_T; (right) the inclusive jet cross section shown as data/theory as a function of p_T for CTEQ6M PDF.

is the dominant source of experimental systematic error. The data are in good agreement with the NLO QCD predictions, within the theoretical and experimental uncertainties.

The DØ collaboration measured the inclusive jet cross section with 34 pb^{-1} of data collected during Run 2. Jets are reconstructed with the Run 2 iterative cone algorithm [5] with a cone radius $R = 0.7$. The analysis is restricted to the central pseudorapidity region of $|\eta| < 0.5$. The data quality cuts for jet events are similar to those of CDF. The calorimeter energy is corrected to particle level using information from γ+jet events, low bias triggers and Monte Carlo simulations. Figure 2(left) shows the jet spectrum falling almost by seven orders of magnitude and covering the E_T range from 60 to 560 GeV. In order to see the level of agreement with the theoretical calculations, Fig. 2(right) presents the data to theory ratio. There is agreement within rather large uncertainties. The overall uncertainty is dominated by the jet energy scale.

DIJET MASS CROSS SECTION

Another important probe of QCD is the measurement of the dijet cross section. It provides a handle on parton structure functions at large values of x and also can be used for searches by identifying resonances at high mass.

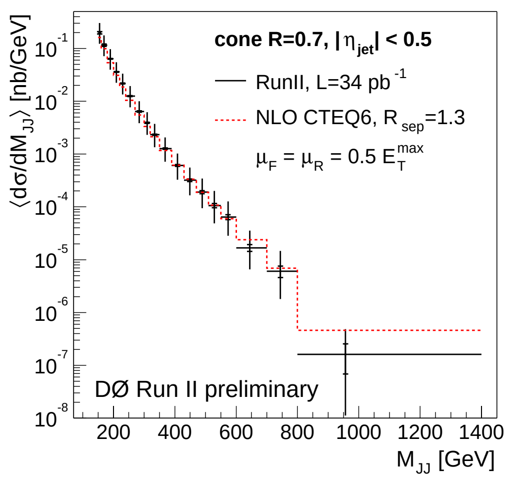

FIGURE 3. DØ dijet cross section as a function of dijet mass. Overlayed on the data are the predictions of a NLO pQCD calculation.

The DØ collaboration measured the dijet mass cross section as a function of the dijet invariant mass. The size of the data sample, requirements for the events and the algorithm used for jet reconstruction are the same as for the inclusive jet cross section measurement. The measured cross section is presented in Fig. 3. The inner bars represent experimental statistical errors and the outer bars are systematic uncertainties; the 10% luminosity uncertainty is not shown. There is an agreement within the errors with the theoretical predictions using CTEQ6M PDF.

The CDF collaboration used 75 pb^{-1} of jet data to search for new particles decaying to dijets by using a general search for narrow resonances and a direct search for several kinds of new particles: axigluons ($A \to q\bar{q}$), excited states of composite quarks ($q^* \to qg$), and E_6 diquarks ($D(D^c) \to \overline{qq}(qq)$). Fitting the mass spectrum with a simple background parametrized function and a mass resonance allows to obtain a 95% confidence level upper limit on the cross section for new particles as a function of mass. A dijet event is defined as an event with the two largest E_T jets, restricted to the pseudorapidity region of $|\eta| < 2.0$. In addition, dijets are required to satisfy the condition $|\cos\theta^*| < 2/3$[1] to supress QCD background. Figures 4(top and bottom) show Run 2 dijet mass spectra compared to Run I data and the ratio of both CDF results compared with lowest order parton level calculations, respectably. CDF excludes at 95% confidence limit axigluons for $200 < M_A < 1130$ GeV/c^2, excited quarks for $200 < M^* < 760$ GeV/c^2, and E_6 diquarks for $280 < M_{E6} < 420$ GeV/c^2.

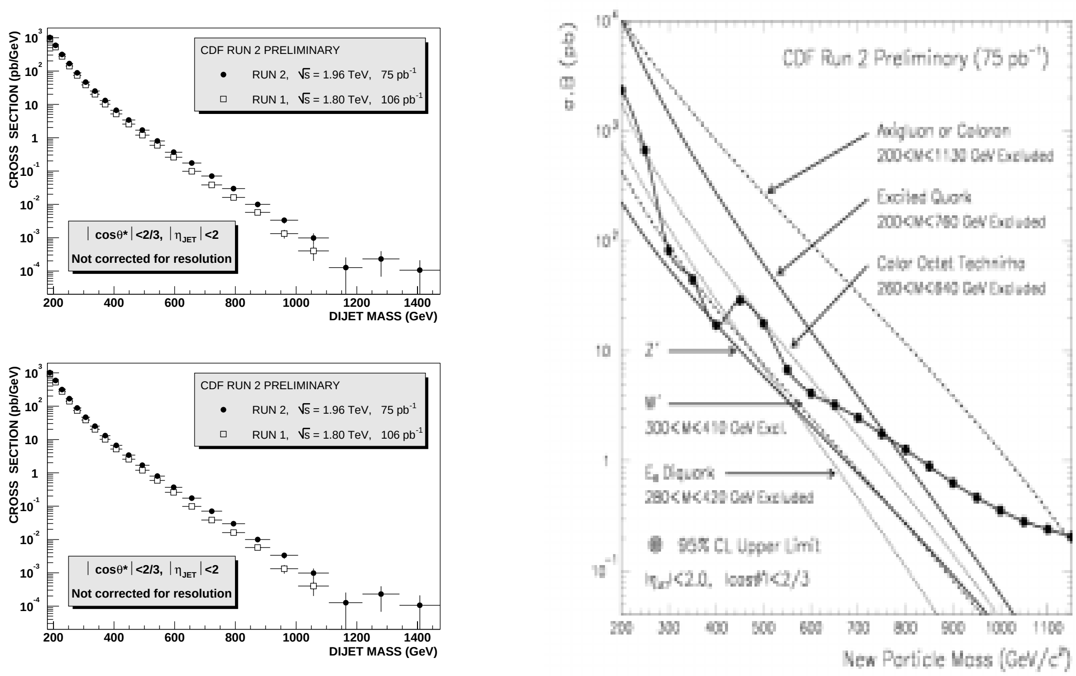

FIGURE 4. (top) CDF dijet mass distribution in Run 2 and Run I presented as a differential cross section in the same mass bins; (bottom) the dijet mass distribution in Run 2 divided by that in Run I is compared to a lowest order parton level calculation(curve); (right) the 95% confodence level upeer linit on the cross section times branching ratio for new particles decaying to dijets.

JET SHAPE STUDIES

The CDF collaboration reports an analysis of jet shapes in inclusive dijet events measured using calorimeter towers. To study the internal structure of jets,integrated jet shape, $\Psi(r,R)$, is defined as the average fraction of jet E_T that lies inside a subcone

[1] $\cos\theta^* = \tanh(\eta^*) = \tanh((\eta_1 - \eta_2)/2)$.

with radius $r < R$. In Fig. 5(left), the jet shape Ψ is shown and compared with the results of a PYTHIA Monte Carlo simulation. The error bars represent the statistical and experimental systematic uncertainties added in quadrature. The MC simulation provides good description of measured jet shapes, but produces jets slightly narrower than the data for low E_T and forward η regions. The low E_T discrepancy can be partially attributed to the fact that the MC simulation underestimates the underlying event component. The measured data distributions also show that jets become narrower as the E_T of the jet increases. This can be observed in Fig. 5(right), where Ψ is shown for fixed $r = 0.4$ in different regions of E_T^{jet} and η^{jet}.

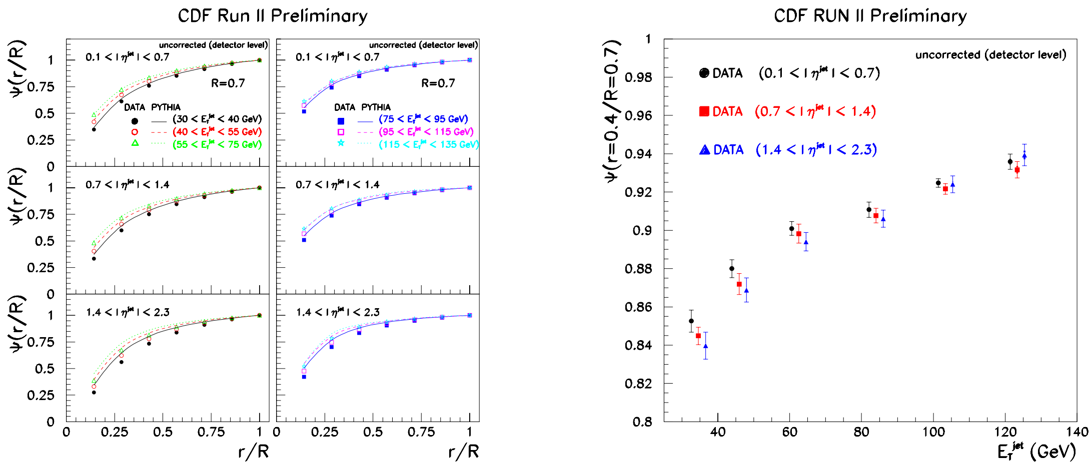

FIGURE 5. (left) CDF measurement of the integrated jet shape in different regions of E_T^{jet} and η^{jet}; (right) measured uncorrected integrated jet shapes, $\Psi(r = 0.4)$. The outer error bars indicate statistical and systematic uncertainties added in quadratures.

CONCLUSIONS AND ACKNOWLEDGMENTS

We presented first Run 2 jet results from the Tevatron. Both CDF and DØ collaborations have accumulated larger data samples and are currently working on reduction of the jet energy scale uncertainties and application of different jet reconstruction algorithms.

We would like to acknowledge the work of all CDF and DØ collaborators that made these results possible.

REFERENCES

1. J. Huston *et al.*, *Phys. Rev. Lett.* **77**, 444 (1996).
2. T. Affolder *et al.*, *Phys. Rev. Lett.* **88**, 042001 (2002).
3. J. Pumplin *et al.*, *JHEP* **0207**, 012 (2002).
4. T. Affolder *et al.*, *Phys. Rev.* D **64**, 032001 (2001).
5. G. Blazey,*et al.*, Proc. of Physics at Run 2: QCD and Weak Boson Physics Workshop, Batavia, IL, FERMILAB-CONF-00-092-E.